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5.2.3 Chillers

In large Federal facilities, the equipment used to produce chilled water for HVAC systems can account for up to 35% of a facility's electrical energy use. If replacement is determined to be the most cost-effective option, there are some excellent new chillers on the market. The most efficient chillers currently available operate at efficiencies of 0.50 kilowatts per ton (kW/ton), a savings of 0.15 to 0.30 kW/ton over most existing equipment. When considering chiller types and specific products, part-load efficiencies must also be compared. If existing chiller equipment is to be kept, there are a number of measures that can be carried out to improve performance.

Opportunities

Consider chiller replacement when existing equipment is more than ten years old and the life-cycle cost analysis confirms that replacement is worthwhile. New chillers can be 30–40% more efficient than existing equipment. First-cost and energy performance are the major components of life-cycle costing, but refrigerant fluids may also be a factor. Older chillers using CFCs may be very expensive to recharge if a refrigerant leak occurs (and loss of refrigerant is environmentally damaging).

An excellent time to consider chiller replacement is when lighting retrofits, glazing replacement, or other modifications are being done to the building that will reduce cooling loads. Conversely, when a chiller is being replaced, consider whether such energy improvements should be carried out—in some situations those energy improvements can be essentially done for free because they will be paid for from savings achieved in downsizing the chiller (see *Section 4.1 – Integrated Building Design*). Be aware that there can be lead times of six months or more for delivery of new chillers.

Technical Information

Electric chillers use a vapor compression refrigerant cycle to transfer heat. The basic components of an electric chiller include an electric motor, refrigerant compressor, condenser, evaporator, expansion device, and controls. Electric chiller classification is based on the type of compressor used—common types include centrifugal, screw, and reciprocating. The scroll compressor is another type frequently used for smaller applications of 20 to 60 tons. Hydraulic compressors are a fifth type (still under development).

Both the heat rejection system and building distribution loop can use water or air as the working fluid. Wet condensers usually incorporate one or several cooling towers. Evaporative condensers can be used in certain (generally dry) climates. Air-cooled condensers incorporate one or more fans to cool refrigerant coils and are common on smaller, packaged rooftop units. Air-cooled condensers may also be located remotely from the chillers.

REFRIGERANT ISSUES

The refrigerant issues currently facing facility managers arise from concerns about protection of the ozone layer and the buildup of greenhouse gases in the atmosphere. The CFC refrigerants traditionally used in most large chillers were phased out of production on January 1, 1996, to protect the ozone layer. CFC chillers still in service must be (1) serviced with stockpiled refrigerants or refrigerants recovered from retired equipment; or (2) converted to HCFC-123 (for the CFC-11 chillers) or HFC-134a (for the CFC-12 chillers); or (3) replaced with new chillers using EPA-approved refrigerants.

All refrigerants listed for chillers by the EPA Strategic New Alternatives Program (SNAP) are acceptable. These include HCFC-22, HCFC-123, HFC-134a, and ammonia for vapor-compression chillers (see table on page 63). Under current regulations, HCFC-22 will be phased out in the year 2020. HCFC-123 will be phased out in the year 2030. Chlorine-free refrigerants, such as HFC-134a and water/lithium bromide mixtures, are not currently listed for phase-out.

A chiller operating with a CFC refrigerant is not directly damaging to the ozone, provided that the refrigerant is totally contained during the chiller's operational life and that the refrigerant is recovered upon retirement. If a maintenance accident or leak results in venting of the CFC refrigerant into the atmosphere, however, damage to the Earth's ozone layer occurs. This risk should be avoided whenever possible.

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Proper refrigerant handling is a requirement for any of the options relating to chillers operating with CFC refrigerants. The three options are containment, conversion, or replacement:

- **Containing refrigerant** in existing chillers is possible with retrofit devices that ensure that refrigerant leakage is eliminated. Containment assumes that phased-out refrigerants will continue to be available by recovering refrigerants from retired systems.
- **Converting chillers** to use alternative refrigerants will lower their performance and capacity. The capacity loss may not be a problem with converted units since existing units may have been oversized when originally installed and loads may have been reduced through energy conservation activities.
- **Replacing older chillers** that contain refrigerants no longer produced is usually the best option for complying with refrigerant phaseout requirements, especially if load reductions are implemented at the same time, permitting chiller downsizing.

SPECIFYING NEW CHILLERS

Chillers have been significantly reengineered in recent years to use new HCFC and HFC refrigerants. New machines have full-load efficiencies down to 0.50 kW/ton in the 170- to 2,300-ton range. Some have built-in refrigerant containment, are designed to leak no more than 0.1% refrigerant per year, and do not require purging.

Other important energy efficiency improvements in new chillers include larger heat transfer surfaces, microprocessor controls for chiller optimization, high-efficiency motors, variable-frequency drives, and optional automatic tube-cleaning systems. To facilitate replacement, new equipment is available from all manufacturers that can be unbolted for passage through conventional doors into equipment rooms. Many positive-pressure chillers are approximately one-third smaller than negative-pressure chillers of similar capacity.

Thermal energy storage may be added when replacing chillers and may enable the use of smaller chillers. Although this strategy does not save energy per se, operating costs may be reduced by lowering electrical demand charges and by using cheaper, off-peak electricity. Thermal storage systems commonly use one of three thermal storage media: water, eutectic salts, or ice. Volumes of these materials required for storage of 1 ton-hour of cooling are approximately 11.4, 2.5, and 1.5 ft^3 (0.33, 0.07, and 0.04 m^3), respectively.

Multiple chiller operations may be made more efficient by using *unequally sized* units. With this configuration, the smallest chiller can efficiently meet light loads. The other chillers are staged to meet higher loads after the lead chiller is operating close to full capacity. If an existing chiller operates frequently at part-load conditions, it may be cost-effective to replace it with multiple chillers staged to meet varying loads.

Double-bundle chillers have two possible pathways for rejecting condenser heat. One pathway is a conventional cooling tower. The other pathway is heat

(continued on next page)

COMPARISON OF REFRIGERANT ALTERNATIVES

Criteria	HCFC-123	HCFC-22	HFC-134a	Ammonia
Ozone-depletion potential	0.016	0.05	0	0
Global warming potential (relative to CO_2)	85	1,500	1,200	0
Ideal kW/ton	0.46	0.50	0.52	0.48
Occupational risk	Low	Low	Low	Low
Flammable	No	No	No	Yes
Source: U.S. Environmental Protection Agency				

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5.2.3 Chillers (continued)

recovery for space heating or service-water heating. Candidates for these chillers are facilities in cold climates with substantial hours of simultaneous cooling and heating demands. Retrofitting existing water heating may be difficult, because of the low temperature rise available from the heat-recovery loop.

Steam or hot water absorption chillers use mixtures of water/lithium-bromide or ammonia/water that are heated with steam or hot water to provide the driving force for cooling. This eliminates global environmental concerns about refrigerants used in vapor-compression chillers. Double-effect absorption chillers are significantly more efficient than single-effect machines. (See *Section 5.2.4 – Absorption Cooling*.)

Specifying and procuring chillers should include load-reduction efforts, careful equipment sizing, and good engineering. Proper sizing is important in order to save on both initial costs and operating costs. Building loads often decrease over time as a result of conservation measures, so replacing a chiller should be accomplished only after recalculating building loads. Published standards such as ASHRAE 90.1 and DOE standards provide guidance for specifying equipment. Procuring energy-efficient, water-cooled electric chillers has been made considerably easier for facility managers through the BOA developed by DOE and GSA that specifies desired equipment parameters.

UPGRADING EXISTING CHILLERS

A number of alterations may be considered to make existing chiller systems more energy efficient. Careful engineering is required before implementing any of these opportunities to determine the practicality and economic feasibility.

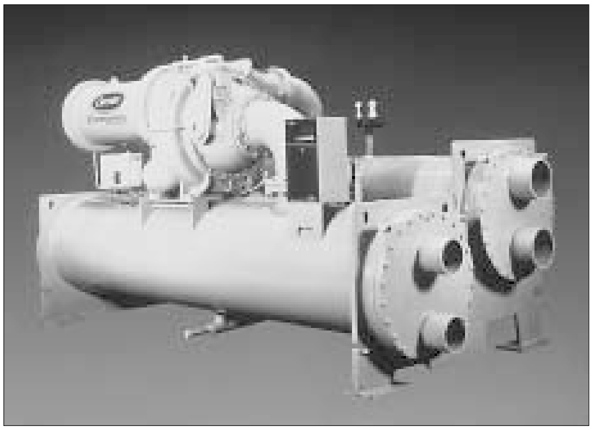
Variable-frequency drives provide an efficient method of reducing the capacity of centrifugal chillers and thus saving energy. Note that VFDs are typically installed at the factory. Savings can be significant, provided that (1) loads are light for many hours per year, (2) the climate does not have a constant high wet-bulb temperature, and (3) the condenser water temperature can be reset higher under low part-load conditions. (See *Section 5.7.2 – Variable-Frequency Drives*.)

Chiller bypass systems can be retrofitted into central plants, enabling waterside economizers to cool spaces with chillers off-line. In these systems, the cooling tower provides chilled water either directly with filtering or indirectly with a heat exchanger. These systems are applicable when (1) chilled water is required many hours per year, (2) outdoor temperatures are below 55°F (13°C), (3) air economizer cycles cannot be used, and (4) cooling loads below 55°F (13°C) do not exceed 35–50% of full design loads.

Other conservation measures to consider when looking at the chiller system upgrades include:

- Higher-efficiency pumps and motors;
- Operation with low condenser water temperatures;
- Low-pressure-drop evaporators and condensers (oversized chiller "barrels");
- Interconnecting multiple chillers into a single system;
- Upgrading cooling towers; and
- Upgrading control systems (e.g., temperature reset).

> **Overall HVAC system efficiency** should be considered when altering chiller settings. The complex interrelationships of chiller system components can make it difficult for operators to understand the effects of their actions on all components of the systems. For example, one way to improve chiller efficiency is to decrease the condensing water temperature. However, this requires additional cooling tower operation that may actually increase total operating costs if taken to an extreme. In humid climates, increasing the chilled water temperature to save energy may unacceptably reduce the effective removal of humidity if the coil size is not also adjusted.



Carrier Corporation's Evergreen line of chillers was the first one specifically designed to accommodate non-ozone-depleting HFC-134a refrigerant. Source: Carrier Corporation

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Contacts

For more information about the Basic Ordering Agreement (BOA) for energy-efficient water-cooled chillers, contact the General Services Administration at (817) 978-2929.

☑ ROOFTOP RETROFITS

Many Federal buildings are cooled via roof-mounted direct-expansion (DX) air conditioners. If the individual rooftop DX units are old and inefficient, it may be possible to retrofit them to use a single high-efficiency chiller (18 or higher energy-efficiency rating [EER]). In the retrofit process, the existing evaporator coils are adapted to use glycol that is cooled by the chiller. Ice storage may be incorporated as part of the rooftop retrofit. The chiller can be operated at night to make ice, which would provide or supplement cooling during the day. This retrofit system provides an efficient means of reducing on-peak electric demand, as discussed in this section under *Thermal Storage.* FEMP estimates a very high savings potential from this system. If all rooftop DX systems used in Federal buildings were replaced by chillers, more than 50% of the electricity used by rooftop units could be saved. Available space for the chiller and, if included, ice storage, is a consideration with this type of retrofit.